

BENEFITS OF BREAKFAST IN ADOLESCENTS

By

Erin M Racki

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Chairperson - Dr. Heather Leidy, Ph D

Committee members

Dr. Debra Sullivan, Ph D, RD

Mr. Pete Beyer, MS, RD

Date defended: _____

The Thesis Committee for Erin Racki certifies that this is
the approved Version of the following thesis:

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Committee:

Chairperson - Dr. Heather Leidy, Ph D

Date approved: _____

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Chapter 1 – Introduction

The goal of the Healthy People 2010 initiative is to promote health and reduce chronic disease associated with diet and body weight [1]. However, the current trends in overweight and obesity indicate that Americans are moving farther away from this goal [1]. It is estimated that by the year 2030, 86% of Americans will be overweight or obese [2]. Even more unsettling is the fact that a large percentage of these individuals will be comprised of children and adolescents.

The severity of the adolescent overweight and obesity epidemic is considered to be the most serious long-term health risk currently facing this age group [3]. Unhealthy weight gain can lead to the development of a number of health-comprising conditions including diabetes, cardiovascular disease, and metabolic syndrome [4]. In fact, recently, obese adolescents were found to have arteries similar to those of middle-aged adults, increasing the risk of a heart attack, stroke, and premature cardiovascular disease [5]. Not only do these conditions reduce quality of life during adolescence, there is strong evidence that most overweight children and adolescents will become obese adults further reducing quality of life and life expectancy [4]. Current lifestyle practices and behaviors such as physical inactivity and poor dietary choices are the primary contributors to this epidemic.

One of the more common dietary practices among adolescents includes skipping breakfast. Recent evidence supports that this behavior is associated with several unhealthy dietary habits including increased consumption of high sugar, high calorie snacks [6-8] and consuming large amounts of food in the evening [9]. All of these habits may lead to a surplus of calories consumed. Over time, these additional calories may lead to weight gain,

reduced body weight management, and obesity. Unhealthy food preferences [10], increased appetite [11], and increased food cravings [12] may also result from missing the breakfast meal. Lastly, breakfast skipping has also been associated with other negative behaviors involving reduced academic performance [11, 13], increased substance abuse, and various emotional problems [14]. The development of these unhealthy eating habits during adolescence is likely to continue into adulthood [4]. Thus, encouraging breakfast consumption may be an important step toward improving overall health and well-being and decreasing the obesity problem in this age group. However, it is unclear whether the composition of breakfast plays a role in the additional health benefits of breakfast.

The current recommended dietary allowance (RDA) for protein is $0.85 \text{ g protein} \cdot \text{kg}^{-1} \cdot \text{d}^{-1}$ for adolescents 14-18 years old [15]. Previous research in adults has shown that diets higher in protein lead to reduced meal-related and overall perceived hunger [16-18], increased perceived fullness (satiety), [16, 18-20] and reduced overall energy intake [21, 22] compared to diets containing the RDA for dietary protein. Limited and conflicting evidence exists concerning the effects of increased dietary protein in children and adolescents. While a higher protein lunch meal was shown to increase postprandial feelings of satiety compared to a normal protein meal [23], diets higher in dietary protein have led to no changes in body weight or daily appetite vs. normal protein diets [24, 25]. As to whether the consumption of dietary protein in the morning positively influences daily appetite, a recent study in adults found that a protein-rich breakfast led to greater immediate and sustained satiety compared to a normal protein breakfast [26]. No studies to date have examined the impact of increased protein intake at breakfast in adolescents who typically skip this morning meal.

While there appears to be numerous beneficial effects of consuming dietary protein, there may be unhealthy changes in food preferences and food cravings following high protein diets. Previous research has shown that protein-rich meals lead to a greater aversion to protein containing foods and increased intake and cravings for sweet, carbohydrate rich foods compared to carbohydrate-rich meals [27, 28]. Previous research in young children shows similar findings such that the consumption of a protein-rich lunch meal (46 grams of protein) led to lower protein consumption at dinner while carbohydrate intake remained unchanged [29]. These preferences and cravings may be due to the fact that diets higher in dietary protein often contain a smaller amount of calories from carbohydrates. The brain's preferred energy source is carbohydrates; thus, when glucose availability is limited, various peripheral and central signals may become activated to increase hunger sensations, food cravings and increased preference for carbohydrate-rich foods. These behaviors likely lead to increased food intake until carbohydrate needs are met [30]. While the current study does not restrict calories or carbohydrates long-term, it can provide useful information concerning whether eating a protein rich breakfast leads to unfavorable changes in food cravings and food preferences. Food choices over long periods of time may lead to unhealthy eating practices, poor adherence to diets, and increased risk for chronic diseases.

Broad Aim:

To identify whether the incorporation of breakfast leads to beneficial improvements surrounding the regulation of food intake in breakfast-skipping adolescents.

Primary Aims:

1. To examine the effects of breakfast, regardless of macronutrient composition, on appetite and subsequent food intake in breakfast-skipping adolescents.

Hypothesis: Compared to skipping breakfast, the incorporation of breakfast will lead to reductions in post-meal hunger and prospective food consumption, increases in post-meal fullness (satiety), and decreases in subsequent meal (lunch) total energy intake.

2. To examine the effects of a protein-rich breakfast (38% protein, 13% Fat, 49% CHO) on appetite and subsequent food intake in breakfast-skipping adolescents.

Hypothesis: Compared to eating a breakfast containing the RDA for dietary protein (14% protein, 13% Fat, 73% CHO), the protein-rich breakfast will lead to greater reductions in post-meal hunger and prospective food consumption, increases in post-meal fullness (satiety), and decreases in subsequent meal (lunch) total energy intake.

Outcomes: 4-h post-meal perceived hunger, fullness (satiety), and prospective food consumption

Ad libitum lunch energy intake (total energy content)

Secondary Aim:

To examine the effect of a protein-rich breakfast (38% protein, 13% Fat, 49% CHO) on food preferences and food cravings in breakfast-skipping adolescents.

Hypothesis: While “high protein/low carb” diets/meals typically lead to greater food preferences for carbohydrates along with increased cravings for sweet foods, the

protein-rich breakfast in the proposed study, which includes adequate quantities of protein and CHO, will produce no food preferences or food cravings.

Outcomes: Food preferences: Ad libitum lunch foods chosen to consume
4-h post-meal food cravings (sweet, salty, meat)

Chapter 2 – Literature Review

Prevalence of Overweight and Obesity:

Obesity is a major world health problem affecting over 250 million people (7%) of the total population [31]. Even more alarming is the fact that the prevalence of overweight has doubled among children 6-11 years old and tripled among 12-17 year olds in the United States between 1980 and 2000 [31]. In 2006, the National Health and Nutrition Examination Survey indicated that 17.1% of US children and adolescents aged 2-19 years were overweight [32]. A more recent analysis has indicated that 1 in 3 kids (33%) in the US are now overweight [33]. While the rate of overweight and obesity has slowed over the past several years, we are still well-below the goals of the Healthy People Initiative [1, 34].

Defining Overweight and Obesity in Children and Adolescents:

Overweight and obesity status can be defined in children and adolescents by using the sex-specific body mass index (BMI) for age growth charts from the Centers for Disease Control and Prevention [34]. Prior to 2008, the CDC classified a young person as at-risk for being overweight if his/her BMI for age was at or above the sex-specific 85th percentile but less than the 95th percentile. Additionally, a child was considered overweight if his/her BMI for age was at or above the sex-specific 95th percentile [34]. However, in 2008, the CDC redefined these percentiles as overweight and obese, respectively.

Consequences/Health Issues of Overweight and Obesity in Children and Adolescents:

In general, unhealthy weight gain at any stage increases the risk for diabetes, heart disease, hypertension, asthma, sleep disorders, nonalcoholic fatty liver disease, and some types of cancers [4, 31]. The greater the excess weight, particularly abdominal weight, the higher

the risk for developing chronic diseases and associated complications throughout life [31, 35]. The health consequences related to overweight can begin as early as childhood and further increase risk later in life. It has previously been reported that nearly 60 percent of overweight children have at least one cardiovascular risk factor and 25 percent have two or more risk factors [36].

One particular health concern facing children and adolescents is the rise in the development of metabolic syndrome [37]. Metabolic syndrome includes components such as overweight, high triglycerides, low HDL, impaired glucose tolerance, and high blood pressure. If left untreated, these conditions can lead to heart disease, diabetes, and obesity, increasing morbidity and decreasing quality of life. The overall prevalence of metabolic syndrome was found to be 3.5% in a large observational study of 4,450 US adolescents aged 12-19 years old; however, the prevalence was much higher in adolescents with a BMI $\geq 95^{\text{th}}$ percentile (14.5%) compared to adolescents with a BMI $<85^{\text{th}}$ percentile (0.9%) [38]. A smaller study showed the prevalence of metabolic syndrome to range from 29% to 40% in overweight adolescents and as high as 50% in severely obese individuals [37]. The high prevalence of overweight and metabolic syndrome in young people may be the primary reason why this generation will most likely have a shorter life expectancy than their parents [39].

Overweight and obesity may also be associated with psychological issues such as poor self esteem [40], depression [41], poor self views [41, 42], and other emotional consequences [42]. In a review article, the psychological effects of being overweight or obese were examined in 50+ children [40]. All overweight or obese children reported some degree of negative psychological impact from being overweight or obese [40]. A cross-

sectional study in Sweden evaluated the health and lifestyle components among 15 year old boys [42]. This study indicated that the obese boys were less satisfied with their weight and appearance, had fewer friends, did not enjoy school, had more absences from school, and were involved in more violence compared to their normal weight counterparts [42]. In addition, the obese boys were bullied, used drugs, displayed suicide thoughts, and showed psychological symptoms more frequently compared to normal weight boys [42].

Taken together, it is essential to identify and implement any and all intervention strategies that successfully target weight control in the youth population to reverse the obesity epidemic and prevent or delay serious health complications.

Potential Causes of Overweight and Obesity in Adolescents:

There are many factors contributing to the rise in child and adolescent overweight and obesity. While genetics and family history play a significant role, physical inactivity, the obesigenic environment, and numerous dietary habits can greatly influence energy balance and body weight control.

Decreasing physical activity and participating in more sedentary activities such as increased television watching or playing video games may lead to unwanted weight gain. The risk of being overweight has been shown to increase by 16% with every hour of watching television [43]. Additionally, the risk of having excess body fat also increases by 27% with every hour of watching television and 9% with every hour of weekend videogame usage [43]. Additionally, boys and girls that watched fewer hours of television exhibit lower odds of weight gain regardless of their physical activity levels. However, girls with greater television viewing and lower physical activity levels appear to have the highest chance of becoming overweight [44].

On the other end of the energy spectrum, the food environment and dietary habits have dramatically changed over the past several years. There has been a dramatic increase in portion sizes and foods containing higher amounts of saturated fat or trans fat [45, 46]. This can likely be attributed to the increase in consuming pre-packaged and fast food meals [47]. Frequent snacking between meals is also a very common dietary habit. Snacking tends to contain little nutritional value and provides excessive discretionary calories filled with added sugars and fat [48]. Children and adolescents also consume large quantities of sugar-sweetened beverages including soda, fruit juices, and energy drinks [8, 31, 49]. These drinks are high in calories, low in nutrients and often replace other more healthy beverages like milk, 100% juice, and water [31, 49]. Together, these unhealthy practices may lead to over-eating, weight gain, and obesity [47].

Skipping breakfast is the most common unhealthy practice in adolescents. Breakfast may be the most important meal of the day, yet adolescents are more likely to skip this meal compared to any other meal [50]. Frequent breakfast-skipping is a common practice among the youth for various reasons such as a lack of time, oversleeping, or not liking the food available [51-53]. Among children and adolescents, it is estimated that 12-34% regularly skip breakfast. This behavior tends to increase with age and is more common among adolescent girls [54]. Previous research has shown there are numerous negative consequences related to breakfast-skipping.

A very strong association has been consistently observed between breakfast skipping and overweight and obesity [55, 56]. Skipping the morning meal has even been found to be predictive of increases in BMI and weight gain later in life [6]. This strong

relationship may be due to the increased food quantity, poor food quality, and unhealthy eating practices that are observed with skipping breakfast [57].

Missing meals, particular the first meal of the day, leads to overeating at subsequent meals, especially at dinner [9]. In fact, young Canadian “breakfast skipping” children were found to overeat at dinner (≥ 700 calories) [55]. Concerning food quality, previous research has shown that the percentage of children consuming at least two-thirds of the Recommended Dietary Allowance (RDA) for several nutrients was much lower in kids who skipped breakfast [58]. Skipping breakfast is also associated with fewer servings of fruits and vegetables (not meeting recommendations), increased sugar consumption [59-61], and frequent consumers of unhealthy snacks [8, 59, 60]. Overall poor eating habits and unhealthy diets are observed in non-breakfast eaters.

Abnormal food preferences and food cravings may also develop when the breakfast meal is skipped. Children who skip breakfast have stronger feelings for and greater consumption of unhealthy items including high fat and sugar snacks and more negative feelings towards healthy items such as fruit, bread, milk, and cereal compared to eating breakfast [12].

Lastly, skipping breakfast is suggested to impair cognitive performance due to the continuation of the overnight fasting condition when the morning meal is not consumed [13]. Greater feelings of hunger may result due to the prolonged period without eating which may significantly influence an adolescent’s ability to focus and learn in school. Previous research indicates that increased hunger led to declines in attention and memory, impairing children to learn throughout the day [11, 13, 62-64]. Specifically, breakfast skippers are slower to recall information from memory [62], have a reduction in problem

solving abilities [62], commit more errors on school work [11], and receive lower scores in math and cognitive activities [63-65]. Past research has shown that children who miss breakfast displayed more behavioral, emotional, and academic problems compared to kids who consistently eat breakfast [14]. Breakfast skippers tend to be more absent from school or have more tardy days [66].

The dietary practices briefly described above are very common among adolescents and will more than likely continue into adulthood further impacting body weight and overall health [4]. Thus, it is critical to identify those dietary practices that lead to better body weight management and long-term health.

Potential Dietary Strategies-Incorporation of Breakfast:

Breakfast can be defined as the first eating occasion of the day. This meal is usually consumed before 10:00 am and typically consists of 500 calories, making up 20%-35% of total daily energy needs [61]. Regular consumption of breakfast may have a multitude of health benefits for children and adolescents [50] including increased intake of essential nutrients, improved academic performance, improved behavior, increased satiety, decreased hunger and decreased food intake [58].

Observational studies showed that regular breakfast consumption leads to a higher quality diet with increased amounts of fiber, calcium, vitamin A, vitamin C, riboflavin, zinc, and iron as well as decreased intake of calories, fat and cholesterol compared to skipping breakfast [58]. Incorporating the breakfast meal could also lead to improvements in blood lipid and insulin profiles if the meal is of high quality [58, 67].

Eating a morning meal provides the brain with the necessary energy to perform cognitively and increase learning. Eating breakfast has been associated with improved

learning and enhanced school performance [11, 58, 66]. More specifically, breakfast enhances tasks involving processing of a complex visual display, spatial memory, short-term memory, and auditory attention [58]. Research examining the impact of school breakfast programs on cognitive function found that eating breakfast led to beneficial effects in children's behavior and learning. When breakfast was provided at school, children demonstrated lower absence and tardiness rates [58], decreases in suspensions [58], fewer other disciplinary conflicts [66] and greater attention and energy to learn [58].

The composition of the breakfast may impact these outcomes. In a review article, the relationship between the composition of breakfast and body weight was examined [68]. Eating breakfast, especially cereals and associated foods such as fruits, whole grains, and fiber, have been linked to a lower BMI [68]. Regular breakfast eating, specifically whole grains, cereals, and fruit could be protective in weight control, cardiovascular health [68], and other chronic diseases. While the previously mentioned studies have examined the beneficial effects of carbohydrate-rich breakfast meals, limited research has been conducted on whether breakfast meals higher in dietary protein exhibit these same, if not greater, beneficial effects.

Dietary Protein:

Dietary protein serves many important functions. Proteins provide essential amino acids needed for cells and are crucial for overall good health [15]. Protein plays a major role in building and repairing body tissues, supplying energy, keeping nails, hair and skin healthy and regulating processes such as water balance, nutrient transport and muscle contraction [15]. Reaching adequate amounts of protein in the daily diet is very important for people of all ages. Protein is even more critical in growing children and adolescents. The

Recommended Dietary Allowance (RDA) for dietary protein is $0.95 \text{ g protein} \cdot \text{kg}^{-1} \cdot \text{d}^{-1}$ for children 4-13 years old and $0.85 \text{ g protein} \cdot \text{kg}^{-1} \cdot \text{d}^{-1}$ for adolescents 14-18 years old with protein making up between 10-30% of total energy intake [15]. Most adolescents are able to meet protein recommended amounts with the daily diet as the typical American diet provides enough protein sources [69].

Other benefits of dietary protein are its effects on appetite, food intake, and body weight management. In summary, higher protein diets have led to a greater loss of body weight [70-72], fat mass [70-72], and preservation of lean body mass [20, 73] compared to eating a normal protein diet. These differences may be due in part to the increased energy expenditure, through increased thermogenesis, observed with higher protein meals [74]. Due to the primary focus of this research paper, the remaining literature review will consist of the research regarding the impact of dietary protein on appetite and food intake.

Previous research in adults has shown that acute and chronic consumption of increased dietary protein leads to greater meal-related and overall (daily) feelings of fullness (satiety) and/or reduced meal-related and/or overall (daily) hunger compared to consuming the RDA for protein [16-18, 20, 22, 23, 75-78]. This research includes varying amounts/proportions of dietary protein, ranging from 18% to 76% of total energy intake as dietary protein [74].

Previous studies have shown that protein preloads and/or meals of varying content and given on separate occasions resulted in significantly increased feelings of satiety and reduced feelings of hunger compared to carbohydrate and/or fat preloads/meals [74]. While most of the previous studies incorporated “high” protein amounts ($> 40\%$ of total

calories) [74], several showed similar findings with lower protein preloads/meals within the RDA for dietary protein (~30% of total energy content) [74].

The majority of data supports the statement that higher protein diets lead to increased fullness (satiety) [74]. However, some research has found no difference when subjects were given a lunch meal or preload higher in protein [74] while one study found that subjects consistently consuming a higher amount of protein were less satiated by a high protein meal compared to the subjects consistently consuming a lower amount of protein [74, 79].

More recent research consistently shows that higher protein meals influence fullness (satiety), hunger and desire to eat [18, 23, 80, 81]. Younger (ages 21 – 43 years) and older (ages 63-79 years) men completed three 18-day trials of either $1.00 \text{ g protein} \cdot \text{kg}^{-1} \cdot \text{d}^{-1}$, $0.75 \text{ g protein} \cdot \text{kg}^{-1} \cdot \text{d}^{-1}$ or $0.50 \text{ g protein} \cdot \text{kg}^{-1} \cdot \text{d}^{-1}$ [81]. Appetite was assessed throughout each trial. Regardless of age, protein intake did not influence fullness; however, hunger and desire to eat ratings were lower after the $1.00 \text{ g protein} \cdot \text{kg}^{-1} \cdot \text{d}^{-1}$ trial compared to the lower protein trials [81].

In a study involving 38 overweight and obese women, subjects were provided with either a normal protein ($0.20 \text{ g protein/kg body weight}$) or a higher protein ($0.34 \text{ g protein/kg body weight}$) breakfast meal; appetite questionnaires were completed over the remaining 4 hours [20]. The higher protein meal led to greater immediate and sustained satiety compared to a normal protein meal [20]. In another randomized, crossover study, 30 normal to overweight healthy subjects were given either an appropriate protein (10% of lunch energy content from protein) or a higher protein (25% of lunch energy content from protein) meal [23]. Post-prandial fullness (satiety) ratings were measured over 4 hours [23].

Although immediate satiety did not differ among treatments, satiety scores were significantly higher at 30 minutes and 120 minutes following the higher protein lunch compared to the appropriate protein lunch [23].

In summary, there is strong evidence that supports the acute consumption of higher protein meals leads to increased satiety [20, 23, 74] and decreased hunger [81] and desire to eat [80, 81] in adults. These conclusions support other research in that protein is the most satiating nutrient [82]. To our knowledge, no research studies have examined the relationship of increased dietary protein and fullness (satiety) in adolescents.

Chronic consumption of dietary protein also leads to similar appetite responses [17, 18, 22, 78] A study by Moran et al. examined the effect of increased protein (40% of calories) compared to a normal amount of protein (20% of calories) on appetite response in obese men and women over 12 weeks of energy restriction and 4 weeks of energy maintenance [80]. While no significant differences in hunger and satiety were observed, subjects in the higher protein group did report wanting to eat less compared to the normal protein group [80]. In another study, healthy men and women were followed during a 15% protein weight maintenance stage for 2 weeks, followed by a 30% protein stage for 2 weeks and a 30% ad libitum protein stage for 12 weeks [22]. During the ad libitum protein diet, satiety ratings significantly increased compared to the other time periods [22].

Previous research examining increased dietary protein during weight loss found that satiety was maintained following a higher amount of protein compared to the RDA for protein [17, 20]. Specifically, 46 overweight and obese women followed a 12 week energy-restricted diet with either higher protein (30% total energy from protein) or normal protein (18% total energy from protein). Appetite responses were recorded throughout the

intervention [20]. As expected during weight loss, meal-related feelings of fullness were reduced in both groups; however, greater satiety was experienced in those who followed the higher protein diet compared to the normal protein diet [20]. Other researchers observed that during a 6-month weight maintenance period following weight loss, additional protein (30 g/day) led to increased satiety compared to the normal protein group [17].

Overall, higher protein diets lead to increased acute and long-term satiety and/or reduced hunger [17, 18, 20, 22, 70] in adults. However, limited data exists concerning the impact of increased dietary protein in adolescents on appetite.

Concerning the impact of dietary protein on subsequent food intake, the majority of previous studies showed significant reductions in subsequent energy intake when consuming a higher protein preload compared to other preloads [74]. One of the hallmark studies concerning this issue involves an ad libitum feeding trial in which overweight and obese subjects were asked to consume either an increased dietary protein (25% protein) accompanied by ad libitum carbohydrates and fat or a normal protein (12% protein) ad libitum diet [21]. After 6 months, the higher protein group showed a voluntary reduction of 450 kcals/day whereas the normal protein group did not [21]. In a similar study, healthy men and women followed a 15% protein weight maintenance stage, followed by a 30% protein stage and a 30% ad libitum protein stage [22]. During the ad libitum protein diet, the mean spontaneous total energy intake decreased significantly compared to the other diet stages [22]. This suggests increasing protein to 30% of total calories leads to a sustained decrease in calories during ad libitum eating [22].

In summary, a majority of the evidence indicates that higher protein intake leads to a decrease in subsequent food intake in adults; there is once again limited research in adolescents on whether increased dietary protein in the short and long-term leads to reductions in food intake.

While dietary protein has many positive effects in adults, there is limited and conflicting evidence in children and adolescents. A few studies have shown a rise in obesity related to an increase in protein intake [24]. Epidemiological studies have shown that being overweight may be associated with higher protein diets [24]. In contrast, other research in adolescents and children have found similar results to those of adults such as reduced weight [25, 83] and reductions in food intake [29].

Specifically, Rolland et al. examined the effects of controlled diets on weight loss and maintenance in massively obese children for a 3 year period [24]. Children aged 11-16 years with a BMI over the 97th percentile were recruited for the study. Subjects were assigned to either the higher protein diet (19% of total energy content as protein) or the normal protein diet (15% of total energy content as protein) and examinations were done at six different time periods [24]. Both groups followed the prescribed diet until healthy body weight was achieved and then completed a weight maintenance period for the next 2 years [24]. Results showed an average weight loss of 30 kg but a 21 kg regain at the 2 year follow-up with no differences between diet groups [24]. Alternately, Figueroa-Colon completed a study comparing two hypocaloric diets in massively obese children in a weight reduction program [83]. Each subject received either a protein-sparing modified fast diet (600 to 800 kcal) or a hypocaloric balanced diet (800 to 1000 kcal) for 10 weeks. After 10 weeks, all participants were placed on a hypocaloric diet in which calories were increased (1200 kcal)

at 3 months and maintained for 1 year [83]. While both diets produced significant weight loss after 6 months, the protein-sparing modified fast diet had significantly greater changes at 10 weeks (30%) and at 6 months (14%) in the percentage of children who were overweight compared to the hypocaloric balanced diet at 10 weeks (-32%) and 6 months (-18%) [83].

Recent research examined the effect of higher protein diets on anthropometric factors, body composition, appetite and mood in overweight or obese children [25]. A total of 120 children, (Av. BMI: 33 kg/m²; Age: 14 yrs) received either a standard protein diet (15% of total energy content as protein) or a high protein diet (22.5% of total energy content as protein) during a weight loss camp [25]. Outcome measures were taken at baseline and at the end of the study. Body weight and other health measurements were improved throughout the study with no differences between diet groups [25]. Hunger sensations increased and appetite ratings were unchanged over the duration of the weight loss program but did not differ between groups [25].

Previous literature presents conflicting results in terms of increased dietary protein on weight loss [24, 25, 83] and appetite [25] in adolescents. Additionally, research examining the acute effects of increased dietary protein in children and adolescents is very limited. The current study will address this gap in the literature.

One of the potential negative aspects of higher protein diets may be related to unhealthy food preferences and food cravings. Previous research has shown that meals higher in protein lead to a greater aversion to protein containing foods and increased preference for carbohydrate rich foods [27, 28]. In a study involving normal weight healthy women, food preferences were assessed following a high-protein content (43% total

calories) or a high-carbohydrate content (69% total calories) lunch meal [27]. The high-protein lunch led to a greater aversion to the dinner time protein-rich foods compared to the lunch higher in carbohydrate [27]. Another study evaluated the effects of meals with varying macronutrient composition on food cravings and mood [28]. The protein-rich meal led to the greatest cravings for sweet, carbohydrate-rich foods compared to the high-carbohydrate and mixed meals [28]. This suggests an increased amount of dietary protein at one meal may lead to a decrease in protein or protein-containing foods and an increase in cravings for sweet tasting foods at the subsequent meal in certain individuals. These cravings may be due to the brain's preference for carbohydrates as the main energy source [30]. The maintenance of the glucose supply to the tissues is regulated by glucose sparing and when glucose does not reach adequate levels, various signals may increase hunger sensations, food cravings and preferences for carbohydrate containing foods [30]. These cravings and preferences may cause increased food intake until sufficient glucose levels are met and detected by the brain [30]. The current study will provide information on whether eating a protein-rich breakfast leads to changes in food preferences and food cravings in adolescents. Unhealthy food preferences and cravings over a long period of time in this age group could lead to poor eating habits and the development of chronic diseases.

Timing of Dietary Protein-Breakfast:

A substantial amount of data exists concerning the effects of increased dietary protein on appetite and food intake. However, the following gaps in the literature still exist: 1.) the studies previously described examined the differences in higher vs. normal dietary protein at the breakfast meal; thus, it would be interesting to identify whether the timing of protein consumption influences the satiating properties of dietary protein; 2.) since the majority of

these studies were performed in adults, it is unknown whether growing adolescents will respond in a similar manner; and 3.) the previous studies were completed in subjects who consistently eat breakfast; thus, it is important to determine how breakfast skipping individuals would respond to eating breakfast on a daily basis.

Concerning the first knowledge gap, one recent study has examined this issue. Nine men (Av. age – 48 years; Av. BMI – 32.7) completed five feeding trials of 3 days energy balance followed by 3 days energy restriction (750 kcal/day) [26]. Subjects were provided with a normal protein (0.80 g protein/kg/day) or a higher protein (1.4 g protein/kg/day) diet at breakfast, lunch, dinner or divided equally between all meals. Questionnaires evaluated the meal-related and overall feelings of fullness [26]. The higher protein breakfast was found to lead to greater immediate and sustained satiety compared to a normal protein breakfast as well as when the higher protein was given a lunch and dinner [26]. This research study shows that the timing of a higher protein meal influences immediate and longer satiety compared to a normal protein meal. The purpose of this research project is to address the second and third literature gaps.

Summary:

Overweight and obesity has become a major health problem and is of major concern in children and adolescents. Unhealthy weight gain can lead to the development of a number of healthy-comprising conditions including diabetes, cardiovascular disease, and metabolic syndrome [4]. Not only do these conditions reduce quality of life during adolescence, there is strong evidence that most overweight children and adolescents will become obese adults, further reducing quality of life and life expectancy [4]. One of the more common unhealthy dietary practices among adolescents involves skipping the

morning meal. Data suggests that breakfast skipping may lead to over-eating throughout the day, weight gain, and obesity in young people [6-9, 11, 13, 14]. Dietary interventions need to be determined to help prevent these unhealthy consequences.

Previous research in adults has shown that diets higher in protein lead to reduced meal-related and overall perceived hunger, [16-18, 20] increased perceived fullness (satiety) [16, 18-20] and reduced overall energy intake [21, 22] compared to diets containing the RDA for dietary protein. The current study will examine the impact of increased dietary protein at the breakfast meal on appetite, food preferences and cravings, and subsequent food intake in breakfast-skipping adolescents.

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Chapter 3

The Effect of a Protein-Rich Breakfast on Appetite Response, Food Cravings, and Subsequent Food Intake in Breakfast-skipping Adolescents

Erin M. Racki¹, Candace Coffey², and Heather J. Leidy¹

¹Dept. Dietetics & Nutrition; University of Kansas Medical Center, Kansas City, KS

²School of Medicine; University of Kansas Medical Center, Kansas City, KS

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Abstract

Purpose: To examine the effect of a protein-rich breakfast on appetite, food cravings, and subsequent food intake in breakfast-skipping adolescents. **Methods:** 15 healthy, “breakfast skipping” adolescents (age 14 ± 1 y; BMI 79 ± 4 %ile; breakfast 2 ± 1 occasions/wk) randomly consumed, on 3 separate days, a breakfast meal of 24% estimated daily energy needs containing the RDA for protein (18 ± 1 g protein) (PN), a higher amount of dietary protein (48 ± 2 g protein) (PR), or no breakfast (breakfast skipping, BS). Post-meal appetite and food craving responses were collected over a 4-h period followed by an ad libitum lunch buffet.

Results: Following both breakfast meals, hunger was lower vs. BS (-4305 ± 1131 vs. 501 ± 1263 mm•240 min; $P < 0.01$) while fullness was greater vs. BS (4143 ± 1152 vs. 1066 ± 528 mm•240 min; $P < 0.001$). No differences were observed between meals. Both breakfast meals also led to a decrease in prospective food consumption vs. BS (-4100 ± 758 vs. 1304 ± 868 mm•240 min; $P < 0.001$). PR led to a greater reduction vs. PN (trend, $P = 0.06$). No differences in sweet cravings were observed between breakfast meals and BS. PR and PN tended to lead to a greater reduction in salty ($P = 0.062$) and meaty cravings ($P = 0.055$) vs. BS; no differences were observed between meals. The PR and PN breakfast meals led to fewer calories consumed at lunch (434 ± 56 kcal) vs. BS (490 ± 63 kcal; $P < 0.05$). PR led to 127 ± 40 fewer calories compared to 14 ± 23 more calories in PN ($P < 0.005$). **Conclusions:** These findings indicate that the addition of a protein-rich breakfast beneficially impacts appetite control and food intake over the short-term and may potentially be an effective dietary strategy to re-establish energy balance and improve body weight management in overweight and obese young people.

Key Words: obesity, dietary protein, adolescents, breakfast, appetite

Introduction

Obesity is a major medical and public health concern due to the increased risks of a myriad of chronic diseases that reduce quality of life and increase morbidity [1]. It is estimated that by the year 2030, 86% (approximately 260 million) of Americans will be overweight or obese [2], and even more unsettling is the fact that a large percentage of these individuals will be children and adolescents. The severity of the adolescent overweight and obesity epidemic is considered to be the most serious long-term health risk currently facing this age group [3]. Unhealthy weight gain at this critical life-stage can lead to the development of a number of health-comprising conditions including diabetes, cardiovascular disease, and metabolic syndrome which begin at a young age and continue into adulthood [1]. Given the continual rise in childhood and adolescent obesity [4], more effort is needed to identify significant contributors and possible treatment and prevention strategies to combat this epidemic in young people.

A primary contributor to obesity is the increase in unhealthy eating habits, with specific emphasis on breakfast skipping, which has been strongly associated with over-eating, weight gain, and obesity [5-8]. Due to the fact that approximately 66% of adolescents skip breakfast on a daily basis [9], encouraging breakfast consumption may be an important step toward improving overall health and well-being and decreasing the obesity epidemic in this age group. Additionally, it is unclear whether the composition of breakfast plays a role in the additional health benefits of breakfast.

Previous research in adults has shown that diets including a moderate increase in dietary protein lead to greater reductions in total energy intake [10, 11], body weight [12-14], and fat mass [12, 13, 15] along with greater preservation of lean body mass [16, 17]

compared to eating a normal protein diet (i.e., the recommended dietary allowance (RDA)). Increased dietary protein also impacts appetite control and food intake. Specifically, single meals and diets rich in dietary protein lead to post-meal, daily, and long-term reductions in perceived hunger, [18-20], increases in feelings of fullness (satiety) [17, 18, 20, 21], and reduce overall energy intake [10, 22]. When specifically examining whether the timing of protein consumption influences the satiating characteristics of protein, a recent study in adults found that a protein-rich breakfast led to greater immediate and sustained satiety compared to at other meal times (i.e., lunch or dinner) [23]. Taken together, these results further support the concept of incorporating a protein-rich breakfast for improved appetite control and food intake.

While numerous studies support the beneficial effects of a moderate increased dietary protein, there may be unhealthy changes in food preferences and food cravings that accompany increased protein intake. Previous research has shown that meals rich in protein lead to a greater aversion to protein-containing foods along with increased intake and cravings for sweet, carbohydrate-rich foods compared to meals higher in carbohydrates [24-26]. Food choices and preferences over long periods of time may lead to unhealthy eating practices, poor adherence to diets, and increased risk for chronic diseases.

The purpose of this study was to examine the effects of consuming a normal protein vs. protein-rich breakfast meal on appetite, satiety, food craving/preferences, and subsequent food intake in 'breakfast-skipping' adolescents.

Research Methods and Procedures

Subjects

Adolescent boys and girls were recruited from the Kansas City, KS area through advertisements, flyers, and email listserves to participate in the research study. Eligibility was determined by the following inclusion criteria: 1) ages 13-17 y; 2) normal to overweight (50th – 94th percentile for BMI for age and sex); 3) no metabolic diseases or other health conditions; 4) not currently or previously following a weight loss or other special diet in the past 6 months; and 5) infrequent breakfast consumption (<2 breakfast occasions/week). Fifty-five volunteers were interested in participating in the study. Nineteen met the screening criteria and began the study procedures. Fifteen adolescents (8 females, 7 males) from multi-racial and multi-ethnic groups completed the entire study. Four subjects were unable to complete the study procedures due to various reasons, mainly due to difficulty with the blood sampling procedures. All subjects and parents (or legal guardian) were informed of the study purpose, procedures, and risks and signed the assent or consent forms. The study procedures were approved by the University of Kansas Medical Center Human Subjects Committee and the General Clinical Research Center Advisory Committee.

Experimental Design

This is a randomized, cross-over design study consisting of 3 separate testing days lasting approximately 5 hours each day. On separate days, the subjects randomly consumed a normal protein (RDA) breakfast meal (PN), a protein-rich breakfast meal (PR), or no meal (i.e., 'breakfast skipping' (BS)). Pre and post-meal perceived appetite, satiety, and food cravings/preferences were measured throughout the 4-h period (Figure 1). At the end of 4 hours, the subjects were provided with an ad libitum lunch meal in which energy and macronutrient intakes were recorded.

Specific 5-h Testing Day Procedures (Figure 1)

For each testing day, subjects reported to the General Clinical Research Center at the University of Kansas Medical Center after an overnight fast. Subjects were placed in a reclining chair and acclimated to the room for about 10 minutes. Fasting (baseline) perceived appetite, satiety, and food cravings/preference questionnaires were completed prior to breakfast. At time 0, one of the 3 breakfast treatments was given to the subjects and consumed within 15 minutes. Perceived appetite, satiety, and food cravings/preference questionnaires were completed every 20 minutes for the remaining 4 hours. At +240 min, the subjects were provided with an ad libitum lunch buffet and asked to consume this within 20 minutes. The subjects were instructed to eat as much or as little as desired to until feeling 'comfortably full.' The subjects were then allowed to leave the research center. Similar procedures were completed for each of the testing days. There was at least one week separating each testing day.

Baseline Energy Intake

Each subject initially completed a 3-day food record and meal patterning questionnaire during the 3 days immediately before the first testing day. This information allowed us to assess the subject's daily energy intake and eating habits. Additionally, each subject was then required to consume the same foods and quantities recorded on his/her 3-day food record during the days prior to each subsequent testing day. This allowed us to standardize the energy intake consumed prior to each testing day without directly altering the foods and quantities typically consumed by each subject. The subjects were instructed to continue their normal 'breakfast skipping' behavior throughout the study.

Test Meals

The breakfast meals contained 24% of total daily energy intake estimated from the total energy expenditure equations for adolescents in the normal or overweight percentile for BMI for age [27]. The normal protein (PN) meal contained 17.9 g protein \pm 0.8; the macronutrient composition was 14% protein, 73% carbohydrates and 13% fat. The protein-rich (PR) meal contained a higher amount of dietary protein (48.6 g protein \pm 2.2); the macronutrient composition was 38% protein, 49% carbohydrate and 13% fat. Both breakfast meals consisted of pancakes with butter and syrup, scrambled eggs with cheese, and water (266 ml). The two meals were matched for total energy, energy density, dietary fat, fiber and sugar with the only difference being the composition of the pancakes. For the PR meal, a portion of the carbohydrates (i.e., flour) in the PN pancakes was replaced with whey protein powder (See Table 2). For the breakfast skipping trial, subjects did not receive breakfast but were provided with the same amount of water (177 ml) as the other treatments. The breakfast skipping trial served as the subjects' normal eating pattern of skipping breakfast and identifies the normal (baseline) appetite, satiety, food cravings/preferences, and food intake responses.

After consumption of each breakfast meal, subjects were asked to record the palatability rating of the breakfast. The question asked was stated as "rate the following breakfast" with anchors of "extremely unpleasant (1)" to "extremely pleasant (9)."

Appetite/Craving Questionnaires

Computerized questionnaires, assessing appetite sensations (i.e., hunger, fullness, prospective food consumption) and food cravings/preferences (sweet, salty, meaty) were downloaded onto a palm-pilot (Palm, Zire 22, Palm Inc., Sunnyvale, CA) and completed throughout the 5-h testing period (Figure 1). The palm-pilot based AppetiteLog program

(created by the US Department of Agriculture Laboratory/Western Human Nutrition Research Center, Davis CA) uses the validated visual analog scales (VAS) incorporating a 100 mm horizontal line rating scale for each response [28]. The questions are worded in the following manner “how strong is your feeling of” with anchors of “not at all” to “extremely.” Each subject reads each question and, using the palm-pilot stylus, slides across the line and stops once achieving the perceived magnitude of response.

Ad Libitum Lunch

After each 4-h testing period, subjects were provided with an ad libitum lunch buffet. This buffet contained a total of 3000 calories and consisted of commonly eaten food items such as crackers, grapes, strawberries, fig newtons, carrots, meats, and cheeses. Subjects were required to consume 88.7 ml of water at lunch but were provided with additional water to drink ad libitum. Subjects were instructed to eat as much or as little as desired until feeling ‘comfortably full’ within a 20-min time period. Total food intake was measured by weighing all food items before and after the meal. Total energy (calories) and macronutrient composition (grams) was determined using the Nutrition Data System for Research (NDSR; 2006 ver.; Nutrition Coordinating Center; University of Minnesota School of Public Health).

Data and Statistical Analysis

To assess the acute appetite, satiety, and food cravings/preference responses following each of the breakfast treatments, the 4-h postprandial hunger, prospective food consumption, fullness and food cravings/preferences area under the curves (AUC) were calculated from the 12 time points for each testing day. All AUC measurements were calculated using the trapezoidal rule [29]. The data was analyzed by comparing average

responses of the PN and PR meals vs. BS, using a paired-sample t-test. To examine differences between breakfast meals, changes from the BS trial were calculated and compared between the PN vs. PR meals by using a paired-sample t-test. The Bonferroni correction was used to adjust for multiple comparisons. We also sought to identify the predictors of subsequent food intake. The primary outcome (dependent variable) measure was the energy intake measured from the ad libitum lunch buffet. Pearson's correlations were computed between the energy intake at the lunch buffet and our main independent variables which include dietary protein at breakfast, perceived appetite, and food craving responses. Multiple linear regression was used to identify the predictors of subsequent food intake of the variables that were significantly associated with subsequent food intake. Data is expressed as mean \pm standard error of the mean. A test with a p-value < 0.05 was considered statistically significant. Analyses were conducted with the latest version of the Statistical Package for the Social Sciences (Statistical Package for the Social Sciences; version 16.0; SPSS Inc.; Chicago, IL).

Results

Subject Characteristics

A total of 15 subjects (8 females; 7 males) completed all study procedures. The subject characteristics are presented in Table 1. Overall, the subjects were 14 years of age, were normal to overweight (BMI_{ile} of $78.7 \pm 4.1\%$), and skipped breakfast approximately 5 times per week.

Dietary Characteristics

The dietary characteristics of the breakfast meals are shown in Table 2. By design, the amount of dietary fat was held constant ($7.4 \text{ g} \pm 0.3 \text{ g}$ for both meals); the amount of

dietary protein was greater in the PR meal ($48.6 \text{ g PRO} \pm 2.2 \text{ g}$) vs. PN ($17.9 \text{ g PRO} \pm 0.8\text{g}$; $P<0.05$); and total carbohydrate content was lower for the PR ($62.2 \text{ g} \pm 2.8 \text{ g}$) vs. PN ($94.3 \text{ g} \pm 4.3 \text{ g}$; $P<0.05$). While total energy content, fat, sugar, fiber, energy density, and appearance were similar between the breakfast meals, the palatability ratings were different (Table 2). The PN breakfast led to greater perceived palatability (7.6 ± 1.4 – moderately pleasant) vs. the PR meal (4.1 ± 2.2 – slightly unpleasant; $P<0.05$).

Perceived Appetite & Satiety

Perceived appetite and satiety throughout the 4-h post-meal period are shown in Figure 2. Regardless of macronutrient intake, the addition of breakfast led to a greater reduction in post-meal hunger (avg. of both meals: $-4305 \pm 1131 \text{ mm} \bullet 240\text{min}$) compared to skipping breakfast ($501 \pm 1263 \text{ mm} \bullet 240\text{min}$; $P<0.01$) (Figure 2a). No difference in 4-h post-meal hunger was observed between the PN vs. PR breakfast meals. Breakfast also led to greater fullness (satiety) (avg. of both meals: $4143 \pm 1152 \text{ mm} \bullet 240\text{min}$) compared to skipping breakfast ($-1066 \pm 528 \text{ mm} \bullet 240\text{min}$; $P<0.001$) (Figure 2b). No difference in 4-h post-meal fullness was observed between PN vs. PR breakfast meals. Prospective food consumption was also assessed and found to be reduced following the breakfast meals (avg. of both meals: $-4100 \pm 758 \text{ mm} \bullet 240\text{min}$) vs. skipping breakfast ($1304 \pm 868 \text{ mm} \bullet 240\text{min}$; $P<0.001$) (Figure 2c). Unlike perceived hunger and fullness, prospective food consumption tended to differ between meals. When expressed as difference from breakfast skipping, the PR meal led to reduced prospective food consumption ($-7080 \pm 1389 \text{ mm} \bullet 240\text{min}$) vs. the PN breakfast ($-3727 \pm 1294 \text{ mm} \bullet 240\text{min}$; $P=0.06$).

Food Preferences and Food Cravings

Food preferences and cravings including sweet, salty and meaty were also assessed. When combining both breakfast meals, no difference in sweet cravings were observed vs. skipping breakfast (avg. of both meals: $-1962 \pm 1187 \text{ mm} \bullet 240\text{min}$ vs. BS: $493 \pm 1066 \text{ mm} \bullet 240\text{min}$; $P=0.128$). Sweet cravings tended to differ between meals. When expressed as difference from breakfast skipping, the PR meal led to a reduced craving for sweet foods ($-4308 \pm 2190 \text{ mm} \bullet 240\text{min}$) compared to the PN breakfast ($-602 \pm 1111 \text{ mm} \bullet 240\text{min}$; $P<0.05$). Breakfast tended to lead to a greater reduction in post-meal salty cravings (avg. of both meals: $-1372 \pm 944 \text{ mm} \bullet 240\text{min}$) vs. skipping breakfast ($1731 \pm 126 \text{ mm} \bullet 240\text{min}$; $P=0.062$). No differences were observed between PN vs. PR meals. Cravings for meaty foods were found to be reduced following the breakfast meals (avg. of both meals: $-1788 \pm 1457 \text{ mm} \bullet 240\text{min}$) compared to skipping breakfast ($1286 \pm 953 \text{ mm} \bullet 240\text{min}$; $P=0.055$). No differences were observed between PN vs. PR meals.

Subsequent Food Intake

Subsequent food intake eaten at the ad libitum lunch meal is presented in Figure 3. In general, breakfast led to fewer calories consumed at the ad libitum lunch buffet (avg. of both meals: $434 \pm 56 \text{ kcal}$) compared to when no breakfast meal was consumed ($490 \pm 63 \text{ kcal}$; $P<0.05$). When comparing the difference between breakfast meals, the PR breakfast led to fewer calories consumed at the ad libitum lunch buffet compared to the PN breakfast ($P<0.005$) (Figure 3).

Total water intake at lunch was also measured. Each testing day led to an average water ingestion of 210 ml at the ad libitum lunch buffet. No differences in water consumption were observed between breakfast skipping vs. breakfast meals or between meals.

Predictors of Energy Intake

No associations were observed between energy intake at the lunch buffet and the main independent variables of dietary protein at breakfast, perceived appetite, and food craving responses; therefore, the multiple linear regression was not performed.

Discussion

The consumption of a protein-rich breakfast meal led to reductions in post-meal hunger, motivation to eat, food cravings, and subsequent food intake along with increased post-meal feelings of fullness (satiety) in ‘breakfast skipping’ adolescents. These findings indicate that the addition of a protein-rich breakfast beneficially impacts appetite control and food intake over the short-term and may potentially be an effective dietary strategy to re-establish energy balance and improve body weight management in overweight and obese young people.

Several cross-sectional and/or prospective studies have examined the relationship between breakfast skipping and unhealthy eating behaviors. Specifically, individuals who skip the morning meal consume inadequate amounts of dietary fiber, fruits, vegetables, and milk [9, 30, 31] but consume larger amounts of unhealthy foods such as soft drinks, foods high in saturated fat, and high calorie/high sugar snacks [9, 31, 32] compared to those who consume breakfast on a daily basis. Additionally, breakfast skippers also tend to overeat throughout the remainder of the day, especially during the evening hours [33, 34].

Very few intervention-based studies have been completed comparing the effects of breakfast vs. breakfast skipping on appetite and/or food intake. In a study involving 10 normal weight adult women, daily food intake was assessed following 14 days of eating a

500 kcal carbohydrate-rich breakfast consisting of cereal and milk vs. skipping breakfast [35]. Despite the additional calories consumed at the breakfast meal, total daily energy intake was lower following the 14 days of eating breakfast (1663 ± 141 kcal/d) compared to skipping the morning meal (1754 ± 155 kcal/d; $P < 0.05$) [35]. One limitation with this study is the fact that all of the subjects recruited in this study were habitual breakfast consumers. Thus, it is unclear as to whether the addition of breakfast would lead to similar changes in individuals who typically skip the morning meal. While our current study did not assess 24-h energy intake, our current study shows reduced appetite and increased satiety following the addition of a carbohydrate-rich breakfast in breakfast skipping adolescents. However, the beneficial changes in perceived appetite did not lead to reductions in subsequent meal energy intake. This may be because the carbohydrate-rich meal in our study was only provided for 1 day and contained different amounts of macronutrients compared to previous research.

We were also interested in identifying whether the macronutrient composition of the foods (e.g., protein) consumed at breakfast impacts these outcomes. Previous studies in adults have found reduced appetite and increased satiety with protein-rich breakfast meals compared to normal (RDA) breakfast meals [13, 17, 23, 36]. In our previous study, reduced post-meal hunger and desire to eat were observed following a protein-rich (28 g protein) breakfast meal vs. a normal protein (17 g protein) breakfast meal in 38 overweight women during weight loss [20]. Additionally, we also found that when additional protein (64 g protein) was provided at breakfast, lunch, or dinner, meal-related and overall (15-h) fullness was greater following the protein-rich breakfast compared to the protein-rich lunch and dinner meals [23]. However, both studies were completed in adults who consumed

breakfast on a daily basis. Our current study builds upon our previous findings and indicates that a protein-rich breakfast leads to reductions in post-meal hunger and motivation to eat and an increase in post-meal fullness (satiety) in breakfast-skipping adolescents.

Concerning the effect of increased dietary protein on subsequent food intake, several studies have found reduced energy intake at the next eating occasion following a protein-rich meal [24-26]. Specifically, Araya et al. [26] found that children consuming a protein-rich lunch meal (46 g protein) vs. a carbohydrate-rich (12 g protein) lunch consumed less calories at the next eating occasion (1162 ± 281 kcal) compared to the carbohydrate-rich lunch meal (1490 ± 179 kcal; $p < 0.05$) [26]. Barkeling, et al. also evaluated the effects of a protein-rich meal (64.5 g protein) vs. a carbohydrate-rich meal (15.5 g protein) on subsequent food intake and found the protein-rich meal led to greater reductions in energy intake (201 ± 64 g vs. 226 ± 55 g) [24]. Although these studies incorporated increased dietary protein at the lunch meal, our findings show similar reductions in subsequent energy intake when providing the additional protein at breakfast. However, the authors want to point out that even though the protein-rich meal led to a reduced lunch intake by 127 ± 40 kcal compared to the breakfast skipping trial, the 500 calorie breakfast led to a cumulative intake after lunch of 863 ± 40 kcal vs. breakfast skipping (490 ± 63 kcals). Along these lines, the protein-normal meal led to even more calories consumed after the breakfast and lunch meals (total of 1004 ± 23 kcals) vs. skipping breakfast. Because the majority of data suggests that breakfast skipping leads to over-eating in the evening, weight gain, and obesity, other factors may have confounded our results (See the palatability and acclimation

limitations in the following Limitation Section). Additional tracking of 24-h food intake is critical to see if any compensation occurs throughout the remainder of the day.

While protein-rich diets have led to beneficial changes in appetite and food intake, they have also been shown to alter food cravings/preferences [24-26]. Several studies involving children and adults have shown that protein-rich meals lead to a greater aversion to protein-rich foods [24] and increased cravings and preferences for carbohydrate-rich foods [25]. Although these studies did not lead to over-eating, food choices from unfavorable food cravings and food preferences over long periods of time may lead to unhealthy eating practices which contribute to poor diet adherence and chronic diseases. In our study, we found that the protein-rich meal led to a reduction in cravings for sweet foods and no effect on cravings for salty and meaty foods compared to the normal protein meal. This may be due to the fact that both breakfast meals contained an appropriate level of carbohydrates and did not restrict any macronutrients.

Dietary protein is critical to the health and well-being of individuals of all ages providing the essential amino acids for building and repairing body tissues, supplying energy, and regulating body processes. Reaching adequate amounts of protein in the daily diet is even more important for growing children and adolescents. The RDA for dietary protein is $0.85 \text{ g protein} \cdot \text{kg}^{-1} \cdot \text{d}^{-1}$ for adolescents 14-18 years old with protein making up between 10-30% of total energy intake [27]. In the current study, the protein-rich breakfast meal contained an additional 31 grams of protein compared to the normal-protein meal. If the subjects consumed the RDA for dietary protein at both lunch and dinner, theoretically, this would lead to a daily protein intake of $1.30 \text{ g protein} \cdot \text{kg}^{-1} \cdot \text{d}^{-1}$ or 17% of total energy intake which is well-within the normal protein requirements for growing adolescents . Our

current findings suggest that a modest increase in dietary protein leads to additional benefits surrounding appetite control and subsequent food intake when provided at the breakfast meal.

Limitations

Several possible limitations have been identified. The primary limitation in this study was the difference in palatability ratings between the breakfast meals. Specifically, the normal-protein breakfast led to greater perceived palatability (7.6 ± 1.4 – moderately pleasant) vs. the protein-rich breakfast (4.1 ± 2.2 – slightly unpleasant; $P < 0.05$). While both breakfast meals were matched for macronutrients, fiber, sugar, energy density and amount, they were rated differently by the study subjects. It is well established that differences in palatability dramatically influence perceived appetite and subsequent food intake [37, 38]. The palatability ratings were not assessed until after each breakfast treatment was consumed. This was done to allow subjects to consume the entire breakfast and the ratings may have differed due to the high satiating properties of dietary protein.

This study included both normal weight and overweight subjects which may exhibit different responses to dietary treatments. Due to the small sample size ($n=15$) we were unable to make comparisons based on BMI. Second, the subjects included girls and boys. Adolescent boys and girls exhibit different eating habits, attitudes, and thoughts towards food which may lead to different responses in appetite, food cravings, and food intake [39-41].

The subjects were only provided with the normal-protein and protein-rich breakfast meals during the morning of each testing period (i.e., no acclimation to the dietary breakfast treatments was provided prior to these testing days). The subjects did not have time to

adjust to each breakfast meal and were asked to consume the entire meal. Knowing the breakfast treatments in advance and being comfortable with the meals may have led to different responses. While one meal showed significant results, future research testing long-term effects may also be important.

Conclusions

While the addition of breakfast meal leads to beneficial changes in appetite and satiety in 'breakfast skipping' adolescents, additional benefits are experienced with a protein-rich version. Taken together, these findings suggest that the addition of 31 grams of protein consumed at the morning meal may be a useful strategy to combat obesity in overweight and obese young people.

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Table 1: Subject characteristics of 15 'breakfast skipping' adolescent boys and girls

Subject Characteristics	Mean \pm SEM
Gender: Males (n)	7
Females (n)	8
Age (y)	14.3 \pm 0.4
Height (cm)	164 \pm 2
Weight (kg)	64.5 \pm 3.6
BMI Percentile for age and gender) (%ile)	78.7 \pm 4.1
Breakfast Occasions (#/week)	2.0 \pm 0.3

Table 2. Dietary characteristics of the normal protein (PN) and protein-rich (PR) meals

Dietary Characteristics	Normal Protein (PN)	Protein-rich (PR)
Energy Content (kcal)	508 ± 23	507 ± 23
Fat (g)	7.5 ± 0.3	7.4 ± 0.3
CHO (g)	94.3 ± 4.3	62.2 ± 2.8*
Sugar (g)	30.8 ± 1.4	30.4 ± 1.4
Fiber (g)	2.0 ± 0.1	2.0 ± 0.1
PRO (g)	17.9 ± 0.8	48.6 ± 2.2*
Energy Density (kcal/g)	0.75 ± 0.01	0.74 ± 0.01
Palatability Rating	7.6 ± 1.4	4.1 ± 2.2 *

Data Presented as Mean ± SEM; *Paired-sample t-tests PN vs. PR; p<0.05

Table 3. Sample menu of the normal protein (PN) and protein-rich (PR) meals

Normal Protein (PN) Breakfast Meal	Protein-rich (PR) Breakfast Meal
<p>3 Buttermilk Pancakes:</p> <p>Flour 2½ Tbsp</p> <p>Baking Powder ½ tsp</p> <p>Salt ¼ tsp</p> <p>Sugar ½ tsp</p> <p>Skim milk ¼ cup</p> <p>Egg whites 1¼ tsp</p> <p>Margarine 1½ tsp</p> <p>Vanilla Extract ¼ tsp</p> <p>6 ¾ tsp pancake syrup</p> <p>¾ tsp butter</p> <p>¼ cup scrambled eggs</p> <p>1 ⅔ tsp cheese</p>	<p>3 Whey Pancakes:</p> <p>½ cup Designer Whey® protein powder</p> <p>Flour 1¼ Tbsp</p> <p>Baking powder ¼ tsp</p> <p>Salt ⅛ tsp</p> <p>Sugar ¼ tsp</p> <p>Skim milk 2 Tbsp</p> <p>Egg whites ¾ tsp</p> <p>Margarine ¼ tsp</p> <p>Vanilla Extract ⅛ tsp</p> <p>6 tsp pancake syrup</p> <p>¼ tsp butter</p> <p>¼ cup scrambled eggs</p> <p>1 ⅔ tsp cheese</p>

Figure 1: Testing Day Timeline

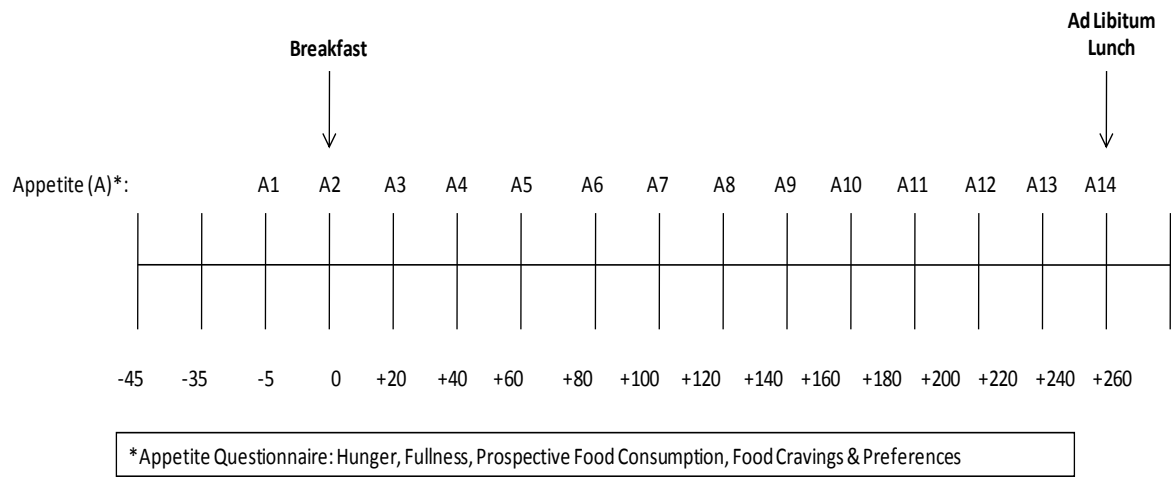


Figure 2: Appetite and satiety responses following the breakfast skipping (BS), normal protein breakfast (PN), and protein-rich breakfast (PR) in 15 'breakfast skipping' adolescent boys and girls

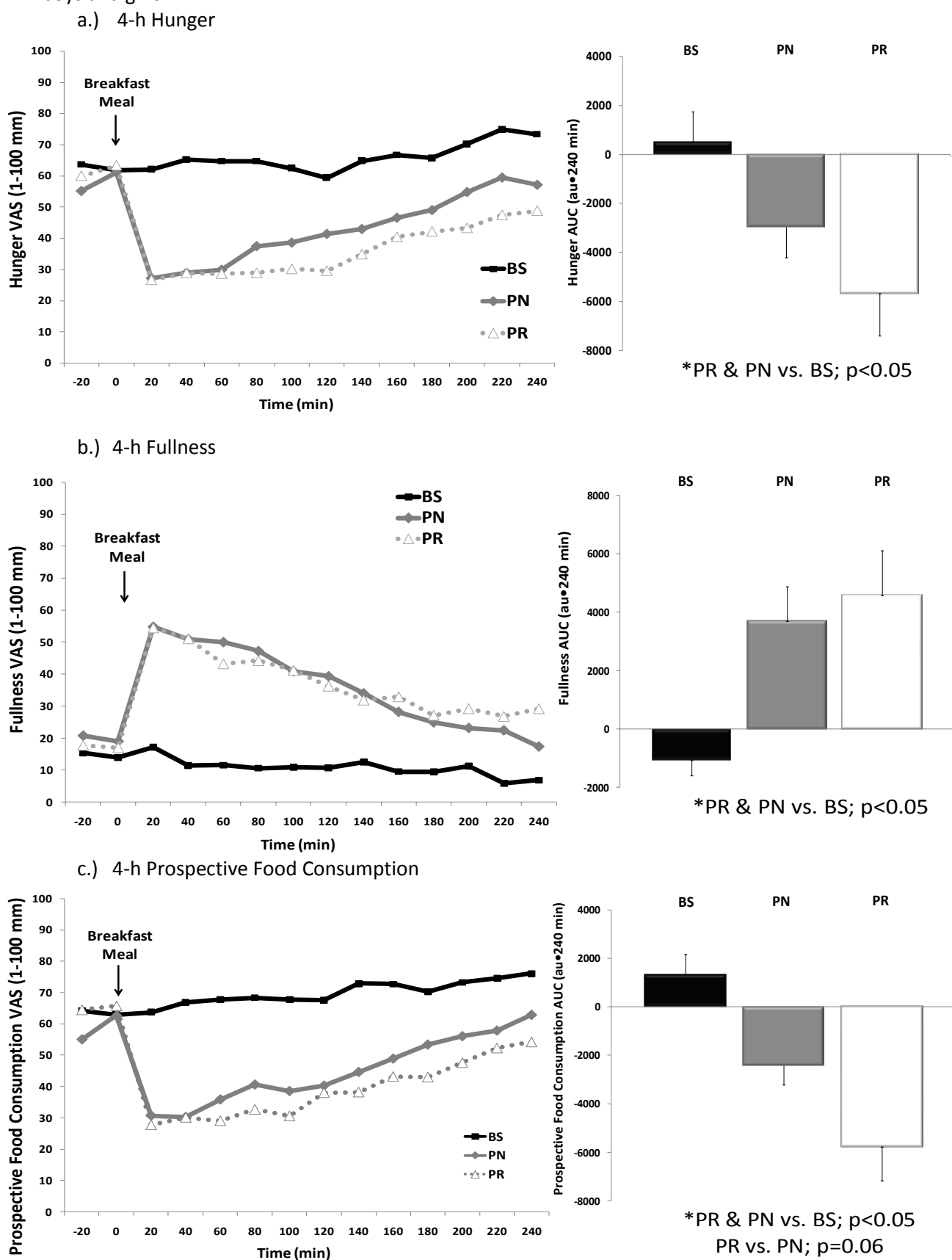


Figure 3: Subsequent food intake (at the ad libitum lunch buffet) following the breakfast skipping (BS), normal protein breakfast (PN), and protein-rich breakfast (PR) in 15 'breakfast skipping' adolescent boys and girls

